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SUBSTRATE TRANSFER APPARATUS, METHOD FOR REMOVING THE SUBSTRATE, AND METHOD FOR ACCOMMODATING THE SUBSTRATE

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

The present invention relates to a substrate transfer apparatus for removing a substrate from, or accommodating or placing a substrate in a substrate accommodating tray, a method for removing the substrate from the substrate accommodating tray using the substrate transfer apparatus, and a method for accommodating the substrate in the substrate accommodating tray using the substrate transfer apparatus. The substrate is used for producing a display panel of, for example, a liquid crystal display device.

2. DESCRIPTION OF THE RELATED ART:

A display panel for a liquid crystal display device usually includes a pair of display glass substrates opposed to each other and sealed together, and a liquid crystal material sealed between the pair of glass substrates. In order to produce such a display panel, glass substrates are transported to a display panel production plant. For transporting the glass substrates, a glass substrate accommodating box for accommodating a plurality of glass substrates is usually used. Glass substrates are used

in display panels of various types of display devices as well as liquid crystal display devices. The above-mentioned type of glass substrate accommodating box is also used for transporting glass substrates used for the various types of display devices other than liquid crystal display devices.

The same type of glass substrate accommodating box is used for transporting glass substrates having electrodes and the like formed thereon as half-finished products, which will be used for producing display panels.

Recently, glass substrates having a thickness of 0.7 mm or less are widely used for various types of display panels. As the glass substrates are increasing in size, the planar area of the glass substrates which are carried to the display panel production plants is increasing, and even glass substrates having a side length of 1.3 m or greater are used.

Such a large and thin glass substrate easily warps. When a plurality of such glass substrates are vertically accommodated in the box with an interval, the glass substrates may warp and contact each other and break during

transportation. In order to avoid this, it is necessary to keep an appropriate distance between the glass substrates in the box.

For example, a glass substrate having a thickness of 0.7 mm and a side length of 1.3 m or greater, when supported along the periphery thereof with a support having a width of 20 to 30 mm in a vertical state may warp by 90 mm or greater at the center thereof. In a glass substrate accommodating box, it is necessary to keep a distance of 100 mm or greater between the glass substrates in the box. This inevitably increases the size of the glass accommodating box.

A glass substrate is removed from a glass substrate accommodating box using, for example, a glass substrate adsorption hand as disclosed in Japanese Laid-Open Publication No. 2001-93969. The glass substrate adsorption hand has a pair of flat adsorption pads. Each adsorption pad needs to be inserted between two adjacent glass substrates, which requires a space for inserting the adsorption pad. A flat adsorption pad usually has a thickness of about 20 mm. Therefore, the distance between the glass substrates in the box needs to be the

sum of a distance sufficient for preventing the glass substrates from contacting each other even when the glass substrates warp and a distance of about 20 mm for inserting the adsorption pad. This also inevitably increases the size of the glass accommodating box.

Due to the necessary space between two adjacent glass substrates, the number of glass substrates which can be accommodated in a glass substrate accommodating box having a prescribed size is limited. This lowers the space efficiency for transportation and storage, i.e., the number of glass substrates which can be accommodated per unit volume.

In order to solve these problems, Japanese Laid-Open Publication No. 10-287382 discloses a substrate tray cassette for accommodating one glass substrate. A substrate accommodating section of the substrate tray cassette has a lattice structure. The substrate tray cassette is structured such that a plurality of substrate tray cassettes can be stacked vertically. Such a substrate tray cassette allows a large and thin glass substrate to be accommodated without warping and thus without being broken during transportation. Since a greater number of

substrate tray cassettes can be stacked vertically for transportation and storage, the space efficiency can be improved.

However, this substrate tray cassette has the following problems. The accommodated glass substrate is supported by resin pins, and a pair of adsorption pads of a glass substrate adsorption hand are put into the space below the glass substrate which is supported by the resin pins. Such a space for the adsorption pads increases the size of the substrate tray cassette.

In order to remove the glass substrate accommodated in the substrate tray cassette using an adsorption hand, it is necessary to separate the plurality of substrate tray cassettes stacked vertically one by one so as to make a large space above the accommodated glass substrate. Accordingly, in order to automatically remove the glass substrate from each of the substrate tray cassettes stacked vertically, a large and complicated apparatus is required.

In order to remove the glass substrate from each of the plurality of substrate tray cassettes stacked vertically and then stack the substrate tray cassettes

vertically after the glass substrates are removed from the substrate tray cassettes, a large work space is required and it is impossible to work efficiently.

SUMMARY OF THE INVENTION

According to one aspect of the invention, a substrate transfer apparatus for removing a substrate from a substrate accommodating tray accommodating the substrate in a horizontal state is provided. The substrate transfer apparatus includes a plurality of support pins for raising the substrate accommodated in the substrate accommodating tray above the substrate accommodating tray. The substrate accommodating tray includes a plurality of openings through which the plurality of support pins are to be inserted. The plurality of support pins are moved up relative to the substrate accommodating tray and are inserted through the plurality of openings of the substrate accommodating tray, so as to raise the substrate. The plurality of support pins each have a length sufficient to be vertically inserted through a plurality of substrate accommodating trays stacked vertically.

In one embodiment of the invention, the substrate

transfer apparatus further includes an elevatable table for raising and lowering the substrate accommodating tray while having the substrate accommodating tray on the elevatable table. The plurality of support pins are inserted through the plurality of openings of the plurality of substrate accommodating trays stacked vertically on the elevatable table as the elevatable table moves down.

In one embodiment of the invention, the elevatable table is moved up and down by a ball screw mechanism.

In one embodiment of the invention, the elevatable table is moved up and down by a belt transport mechanism.

According to another aspect of the invention, a substrate transfer apparatus for removing a substrate from a substrate accommodating tray accommodating the substrate in a horizontal state is provided. The substrate transfer apparatus includes a tray holding unit for holding, in a horizontal state, at least one of a plurality of substrate accommodating trays stacked vertically; and a plurality of support pins for raising a substrate accommodated in a prescribed substrate accommodating tray which is released from the tray holding unit above the prescribed

substrate accommodating tray. The plurality of substrate accommodating trays each include a plurality of openings through which the plurality of support pins are to be inserted. The plurality of support pins are moved up relative to the prescribed substrate accommodating tray and are inserted through the plurality of openings of the prescribed substrate accommodating tray, so as to raise the substrate accommodated in the prescribed substrate accommodating tray.

In one embodiment of the invention, the plurality of support pins are inserted into the plurality of openings of a plurality of substrate accommodating trays released from the tray holding unit, so as to raise the substrate accommodated in the prescribed substrate accommodating tray.

In one embodiment of the invention, the substrate transfer apparatus further includes an elevatable table for raising and lowering at least one substrate accommodating tray released from the tray holding unit while having the at least one substrate accommodating tray on the elevatable table. Where a plurality of substrate accommodating trays stacked vertically are placed on the

elevatable table, the plurality of support pins are inserted through the plurality of openings of the plurality of substrate accommodating trays placed on the elevatable table as the elevatable table moves down, so as to raise the substrate accommodated in the prescribed substrate accommodating tray.

In one embodiment of the invention, the tray holding unit holds each of the plurality of substrate accommodating trays in a horizontal state.

In one embodiment of the invention, the tray holding unit holds at least one of the plurality of substrate accommodating tray in a horizontal state, the at least one substrate accommodating tray accommodating a substrate.

In one embodiment of the invention, the tray holding unit includes an engaging claw to be engaged with the at least one substrate accommodating tray.

In one embodiment of the invention, the tray holding unit holds the at least one substrate accommodating tray by a frictional force.

In one embodiment of the invention, the elevatable table is moved up and down by a ball screw mechanism.

In one embodiment of the invention, the elevatable table is moved up and down by a belt transport mechanism.

According to still another aspect of the invention, a method for removing a substrate accommodated in each of a plurality of substrate accommodating trays stacked vertically is provided. The method includes the steps of (a) separating the lowest substrate accommodating tray, among a plurality of substrate accommodating trays each accommodating a substrate, from the second lowest substrate accommodating trays, among the plurality of substrate accommodating trays each accommodating a substrate, and lowering the lowest substrate accommodating tray; and (b) inserting a plurality of support pins into a plurality of openings formed in the lowered substrate accommodating tray, thereby raising a substrate accommodated in the lowered substrate accommodating tray by the plurality of support pins.

In one embodiment of the invention, the method

further includes the step of (c) transferring the substrate raised by the plurality of support pins. The steps (a) through (c) are repeated.

According to still another aspect of the invention, a method for removing a substrate accommodated in each of a plurality of substrate accommodating trays stacked vertically is provided. The method includes the steps of (a) placing the plurality of substrate accommodating trays each accommodating a substrate on an elevatable table; (b) holding, by a tray holding unit, at least one of a plurality of substrate accommodating trays each accommodating a substrate other than the lowest substrate accommodating tray among the plurality of substrate accommodating trays each accommodating a substrate; (c) lowering the elevatable table and inserting a plurality of support pins into a plurality of openings formed in the substrate accommodating tray placed on the elevatable table, thereby raising a substrate accommodated in the substrate accommodating tray placed on the elevatable table by the plurality of support pins; (d) transferring the substrate raised by the plurality of support pins.

In one embodiment of the invention, the method further includes the steps of (e) after step (d), raising the elevatable table and contacting the substrate accommodating tray placed on the elevatable table with the lowest substrate accommodating tray among the at least one substrate accommodating tray held by the tray holding unit; (f) releasing the at least one substrate accommodating tray from the tray holding unit and placing the released substrate accommodating tray on the elevatable table; and (g) after step (f), performing steps (b) through (d) once more.

In one embodiment of the invention, steps (e) through (g) are repeated.

According to still another aspect of the invention, a method for accommodating a substrate in each of a plurality of substrate accommodating trays stacked vertically is provided. The method includes the steps of (a) placing at least one substrate accommodating tray accommodating no substrate on an elevatable table and inserting a plurality of support pins into a plurality of openings formed in the at least one substrate accommodating tray; (b) placing a substrate on the plurality of support pins

in a horizontal state; (c) raising the elevatable table and accommodating the substrate supported by the support pins in the highest substrate accommodating tray among the at least one substrate accommodating tray; and (d) holding the substrate accommodating tray, accommodating the substrate, by a tray holding unit.

In one embodiment of the invention, the method further includes the step of (e) after step (d), lowering the elevatable table and inserting the plurality of support pins into a plurality of openings formed in at least one substrate accommodating tray accommodating no substrate. Steps (b) through (e) are repeated.

Thus, the invention described herein makes possible the advantages of providing a substrate transfer apparatus for removing a substrate, such as a glass substrate for display or the like, from each of a plurality of substrate accommodating trays stacked vertically and accommodating such a substrate in each of the plurality of substrate accommodating trays stacked vertically with high efficiency; a method for removing the substrate using the substrate transfer apparatus, and a method for accommodating the substrate using the substrate transfer

apparatus.

These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a plan view of an exemplary substrate accommodating tray used for the present invention;

Figure 2 is an isometric view of the substrate accommodating tray shown in Figure 1;

Figure 3 is a partial cross-sectional view of the substrate accommodating tray shown in Figure 1;

Figure 4 is a partial cross-sectional view of a plurality of substrate accommodating trays vertically stacked together, each of which is shown in Figure 3;

Figure 5 is a front view of a substrate transfer apparatus according to the present invention;

Figure 6 is a side view of the substrate transfer apparatus shown in Figure 5;

Figure 7 is a plan view of the substrate transfer apparatus shown in Figure 5;

Figures 8 through 17 are schematic views illustrating an operation of the substrate transfer apparatus shown in Figure 5 for removing a substrate from the substrate accommodating tray shown in Figure 1; and

Figures 18 through 25 are schematic views illustrating an operation of the substrate transfer apparatus shown in Figure 5 for placing a substrate in the substrate accommodating tray shown in Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention will be described by way of illustrative examples with reference to the accompanying drawings.

Figure 1 is a plan view illustrating a substrate

accommodating tray **10** used for the present invention. Figure **2** is a perspective view of the substrate accommodating tray **10**, and Figure **3** is a partial cross-sectional view of the substrate accommodating tray **10** taken along line **A-A** in Figure **1**. The substrate accommodating tray **10** is useful for accommodating a glass substrate used for, for example, a liquid crystal display panel; specifically, a glass substrate having a side length of 1.3 m or greater and a thickness of 0.7 mm or less, for transportation or storage. A substrate transfer apparatus **30** (Figure **5**) according to the present invention is used for, for example, removing the glass substrate **20** from the substrate accommodating tray **10**.

The substrate accommodating tray **10** is molded to be a thin rectangular parallelepiped. The substrate accommodating tray **10** includes a rectangular bottom section **11** for mounting thereon a glass substrate **20** as a display substrate in a substantially horizontal fashion, and a frame **12** for surrounding the entire periphery of the glass substrate **20** when the glass substrate **20** is mounted on the bottom section **11**. The frame **12** is provided along the entire periphery of the bottom section **11**, and projects to a level higher than the level of a top surface of the

bottom section **11**. The bottom section **11** and the frame **12** are integrally molded from a foam polyethylene resin or the like, which is a synthetic resin foam material, or the like. The frame **12** may be provided along the periphery of the bottom section **11** such that the frame **12** surrounds at least a part of the glass substrate **20**.

The bottom section **11** has a rectangular shape which is slightly larger than the glass substrate **20**, and has a thickness of, for example, about 15 mm. The glass substrate **20** is mounted on the top surface of the bottom section **11**.

Square openings **11a** are formed in the vicinity of the corners of the bottom section **11** and at intermediate positions between the corners along the four sides of the bottom section **11**. A square opening **11a** is also formed at the center of the bottom section **11**. Thus, the bottom section **11** has nine openings **11a** arranged in a 3 × 3 matrix. Support pins **34** (Figure 5) can be inserted into the openings **11a** as supporting members. The support pins **34** raise the glass substrate **20** from the bottom section **11** for removing the glass substrate **20** from the substrate accommodating tray **10**.

The frame 12 is provided along the entire periphery of the bottom section 11 as described above, and has a width of about 30 mm. The frame 12 projects to a level higher than the level of the top surface of the bottom section 11 by about 5 mm or greater. The frame 12 surrounds the entire periphery of the glass substrate 20 mounted on the bottom section 11 at an appropriate distance from the edge of the glass substrate 20.

An engaging section 13 is provided along the entire periphery of the frame 12. More specifically, the engaging section 13 is provided such that a step is formed between a bottom surface of the engaging section 13 and a bottom surface of the frame 12, and projects to a level higher than a top surface of the frame 12. The engaging section 13 has a width of, for example, about 30 mm and horizontally projects outward from the frame 12. The engaging section 13 has a rectangular cross-section, and is engageable with a chuck nail (not shown in Figure 1) for chucking. The chuck nail acts as a transfer member for transferring the substrate accommodating tray 10 to a prescribed position. The bottom section 11, the frame 12, and the engaging section 13 may be integrally molded from a foam polyethylene resin

or the like.

A top surface of the engaging section **13** extends horizontally outside and above the top surface of the frame **12**. The frame **12** has a positioning step **14** (positioning portion; Figure **3**), which is provided between the top surface of the engaging section **13** and the top surface of the frame **12**. The positioning step **14** is vertical to the top surface of the frame **12**. The positioning step **14** is provided along the entire periphery of the frame **12**, and acts to determine the positional relationship between the substrate accommodating tray **10** and another substrate accommodating tray **10** which is to be stacked thereon.

In the substrate accommodating tray **10** having the above-described structure, the glass substrate **20** (for example, a glass substrate for a liquid crystal panel having a thickness of 0.7 mm or less) is accommodated on the top surface of the bottom section **11**. A surface of the glass substrate **20** which does not have electrodes or the like is in contact with the top surface of the bottom section **11**. As described above, the bottom section **11** is slightly larger than the glass substrate **20**, and thus the glass

substrate **20** is mounted on the bottom section **11** at an appropriate distance from the edge of the frame **12**.

As shown in Figure **4**, a plurality of substrate accommodating trays **10** (only two are shown in Figure **4** for the sake of simplicity) each accommodating a glass substrate **20** can be stacked vertically and transported in this state. A bottom edge of the frame **12** of an upper substrate accommodating tray (indicated by reference numeral **10a** for the sake of clarity) is engaged with the positioning step **14** of a lower substrate accommodating tray (indicated by reference numeral **10b** for the sake of clarity). Therefore, the substrate accommodating trays **10a** and **10b** stacked vertically do not slip in a horizontal direction with respect to each other.

For example, a plurality of (for example, about 10) substrate accommodating trays **10** each accommodating a glass substrate **20** can be stacked vertically and transported. Each display substrate accommodating tray **10** is thin, and thus significantly improves the space efficiency. As a result, a great number of glass substrates **20** can be transported and stored with high efficiency.

A bottom surface of the frame **12** of the uppermost substrate accommodating tray **10** is engaged with the positioning step **14** of the substrate accommodating tray **10** below. Therefore, there is an appropriate space between the engaging section **13** of the uppermost substrate accommodating tray **10** and the engaging section **13** of the substrate accommodating tray **10** below.

The substrate transfer apparatus **30** (Figure **5**) according to the present invention is usable for removing the glass substrate **20** accommodated in the substrate accommodating tray **10** having the above-described structure. Figure **5** is a front view of the substrate transfer apparatus **30** according to an example of the present invention. Figure **6** is a side view thereof, and Figure **7** is a plan view thereof.

The substrate transfer apparatus **30** includes a supporting base **31**, a tray holding unit **32** provided on the supporting base **31** for holding a plurality of substrate accommodating trays **10** stacked vertically, an elevatable table **33** provided in the supporting base **31** so as to move up and down such that one or a plurality of substrate

accommodating trays **10** released from the tray holding unit **32** are placed thereon and move up and down, and a plurality of support pins **34** provided vertically in the supporting base **31** so as to run through the openings **11a** of one or a plurality of substrate accommodating trays **10** placed on the elevatable table **33**.

The tray holding unit **32** receives the plurality of substrate accommodating trays **10** stacked vertically. The tray holding unit **32** includes a pair of tray side holding sections **32a** facing each other. The tray side holding sections **32a** are provided for holding opposing sides of the substrate accommodating trays **10**.

Each tray side holding section **32a** includes a lengthy plate-like support **32b** (Figure **6**) provided horizontally along the respective side of the substrate accommodating trays **10**, and three tray side engaging members **32c** provided on the support **32b** at an equal interval. The support **32b** is slidable along a pair of slide guides **32d** provided on an upper surface of the supporting base **31** such that the support **32b** moves closer to or farther from the substrate accommodating trays **10** received by the tray holding unit **32**. Such a movement of the support **32b**

is driven by a hydraulic cylinder **32e** provided on the upper surface of the supporting base **31** respectively for each of the tray side engaging members **32c**.

The three tray side engaging members **32c** provided on one support **32b** and the three tray side engaging members **32c** provided on the other support **32b** respectively face each other. On a surface of each tray side engaging member **32c** facing the opposite tray side engaging member **32c**, a plurality of engaging claws **32f** are provided. The plurality of engaging claws **32f** are arranged vertically, and respectively to be engaged with the engaging sections **13** of the plurality of substrate accommodating trays **10** stacked vertically.

The hydraulic cylinders **32e** of one tray holding section **32a** are driven in synchronization with the hydraulic cylinders **32e** of the other tray holding section **32a**. Thus, the pair of supports **32b** move closer to or farther from the substrate accommodating trays **10** in synchronization with each other. The tray side engaging members **32c**, which are provided on the pair of supports **32b**, also move closer to or farther from the substrate accommodating trays **10** in synchronization with each other.

When the tray side engaging members **32c** approach the substrate accommodating trays **10**, the engaging claws **32f** provided on the tray side engaging members **32c** are engaged with the engaging sections **13** of the substrate accommodating trays **10**. By this engagement, the substrate accommodating trays **10** are held horizontally. As long as the tray holding section **32a** holds the substrate accommodating tray **10** by a frictional force, the tray holding section **32a** may have any shape (for example, such a shape as to sandwich the substrate accommodating tray **10** between pair of tray holding sections **32a**).

The elevatable table **33** includes a table section **33a** (Figure 7) provided horizontally such that the substrate accommodating trays **10** are placed thereon. The table section **33a** includes, for example, a rectangular frame **33b** corresponding in shape to the substrate accommodating trays **10**, and a pair of bars **33c** and a pair of bars **33d** arranged in a lattice. The pair of bars **33c** extend substantially parallel to the supports **32b**, and the pair of bars **33d** cross the pair of bars **33c** substantially perpendicularly thereto. The bars **33d** are supported by a supporting arm **33e** at both ends thereof. The supporting arms **33e** are connected to an elevating unit **35**.

Inside the supporting base **31**, a plurality of (nine in this example) support pins **34** are arranged in a 3 × 3 matrix, in correspondence with the openings **11a** of the substrate accommodating trays **10**. Each support pin **34** is provided vertically so as to go through the lattice table section **33a**. As shown in Figure **5**, a top end of each support pin **34** is slightly below the bottom surface of the lowest substrate accommodating tray **10** held by the tray holding unit **32**.

The elevating unit **35** (Figure **6**) is provided for raising and lowering the elevatable table **33**. The elevating unit **35** uses an elevating section **33f** (Figure **7**) for integrally raising and lowering the plurality of supporting arms **33e** of the elevatable table **33**. The elevating section **33f** includes a ball screw mechanism. Specifically, the elevating unit **35** uses an elevating section **33f** for integrally raising and lowering the plurality of supporting arms **33e** of the elevatable table **33**. The ball screw mechanism is of a usual type; namely, includes a ball screw and a slide block engaged with the ball screw. When the ball screw rotates forward, the elevatable table **33** moves up; and when the ball screw rotates

in reverse, the elevatable table 33 moves down. The elevating unit 35 includes a driving motor 35a and a decelerator 35b. The rotation of the driving motor 35a is conveyed to the ball screw mechanism via the decelerator 35b.

With reference to Figures 8 through 17, an operation of the substrate transfer apparatus 30 for removing a substrate 20 from each of the substrate accommodating trays 10 will be described.

The elevatable table 33 of the substrate transfer apparatus 30 is moved up by the elevating unit 35. Thus, as shown in Figure 8, the table section 33a of the elevatable table 33 is positioned between lower portions of the pair of tray side holding sections 32a. At this point, the supports 32b are located so as not to be in contact with the substrate accommodating trays 10 even where the substrate accommodating trays 10 are located therebetween. The tray side engaging members 32c on the pair of supports 32b are also located so as not to be in contact with the substrate accommodating trays 10 even where the substrate accommodating trays 10 are located therebetween.

Then, a plurality of substrate accommodating trays **10** stacked vertically, each accommodating a glass substrate **20**, are placed on the table section **33a**. Thus, the plurality of substrate accommodating trays **10** are located between the three tray side engaging members **32c** provided on one support **32b** and the three tray side engaging members **32c** provided on the other support **32b**.

As shown in Figure **9**, the height of the elevatable table **33** is adjusted such that the substrate accommodating trays **10** are engaged with the engaging claws **32f** provided on the tray side engaging members **32c**, except for the lowest substrate accommodating tray **10**. In other words, the lowest substrate accommodating tray **10** is not engaged with the engaging claws **352f**. When the height of the elevatable table **33** is thus adjusted, the hydraulic cylinders **32e** on the upper surface of the supporting base **31** are driven in synchronization with each other, such that the three tray side engaging members **32c** on one support **32b** and the three tray side engaging members **32c** on the other support **32b** move toward the substrate accommodating trays **10**.

Thus, as shown in Figure **10**, the substrate accommodating trays **10** are engaged with the engaging claws

32f through the engaging sections 13, except for the lowest substrate accommodating tray 10. The substrate accommodating trays 10, except for the lowest substrate accommodating tray 10, are held by the tray holding unit 32. The lowest substrate accommodating tray 10 remains on the table section 33a without being held by the tray holding unit 32.

Then, the elevatable table 33 is moved down by the elevating unit 35. The lowest substrate accommodating tray 10 on the table section 33a is also moved down (i.e., the support pins 34 are moved up with respect to the lowest substrate accommodating tray 10). While the elevatable table 33 is moved down , the support pins 34 provided inside the supporting base 31 go through the lattice table section 33a and are inserted into the openings 11a of the bottom section 11 of the lowest substrate accommodating tray 10.

When the elevatable table 33 is moved further down, as shown in Figure 11, the top end of each support pin 34 contacts a bottom surface of the glass substrate 20 accommodated in the lowest substrate accommodating tray 10. Then, the glass substrate 20 is raised relative to the lowest substrate accommodating tray 10 positionally

relatively while being supported by the support pins **34**. Namely, the top end of each support pin **34** is above the lowest substrate accommodating tray **10**. (The support pins **34** are moved up relative to the substrate accommodating tray **10**.) The glass substrate **20**, when completely raised above the lowest substrate accommodating tray **10**, is held horizontally at a prescribed height while still supported by the support pins **34**.

When the glass substrate **20** is put into this state, the elevatable table **33** is stopped. Then, the glass substrate **20** is released from the support pins **34** and transferred to a prescribed position by a transfer member.

As the transfer member, for example, an adsorption hand as described in Japanese Laid-Open Publication No. 2001-93969 is used. The adsorption hand includes a pair of adsorption pads provided parallel to each other at the same height. Each adsorption pad is a flat plate-like shape and has a thickness of about 20 mm. The adsorption pad can vacuum-adsorb the bottom surface of the glass substrate **20**. The adsorption hand operates as follows. Each adsorption pad is inserted into a position below the glass substrate **20**, which is raised and held

in a horizontal state by the support pins **34**; and is slid upward. The glass substrate **20**, when thus is placed on the adsorption hand, is vacuum-adsorbed to the adsorption hand. Then, the glass substrate **20** is transferred to the prescribed position.

When the glass substrate **20** is removed as described above, the elevatable table **33** is moved up by the elevating unit **35**. Thus, the lowest substrate accommodating tray **10**, from which the glass substrate **20** has been removed, moves up together with the elevatable table **33**. As shown in Figure **12**, the lowest substrate accommodating tray **10** contacts the second lowest substrate accommodating tray **10** (i.e., the lowest substrate accommodating tray **10** among the plurality of substrate accommodating trays **10** held by the tray holding unit **32**). Then, the upward movement of the elevatable table **33** is stopped.

As shown in Figure **13**, the supports **32b** are driven by the hydraulic cylinders **33e** to move farther from the substrate accommodating trays **10**. Thus, the substrate accommodating trays **10** are released from the engagement with the tray side engaging members **32c**, and rests on the substrate accommodating tray **10** which is on the table

section 33a of the elevatable table 33. The lowest substrate accommodating tray 10 does not accommodate a glass substrate 20.

As shown in Figure 14, the elevatable table 33 is moved down by a distance corresponding to one substrate accommodating tray 10. The height of the elevatable table 33 is adjusted such that the substrate accommodating trays 10 are engaged with the engaging claws 32f, except for the lowest substrate accommodating tray 10 with no glass substrate 20 and the second lowest substrate accommodating tray 10 (i.e., the lowest substrate accommodating tray 10 among the plurality of substrate accommodating trays 10 each accommodating a glass substrate 20). When the height of the elevatable table 33 is thus adjusted, the hydraulic cylinders 32e are driven in synchronization with each other, such that the three tray side engaging members 32c on one support 32b and the three tray side engaging members 32c on the other support 32b move toward the substrate accommodating trays 10.

Thus, as shown in Figure 15, the substrate accommodating trays 10 are engaged with the engaging claws 32f, except for the lowest substrate accommodating tray

10 with no glass substrate 20 and the second lowest substrate accommodating tray 10 (i.e., the lowest substrate accommodating tray 10 among the plurality of substrate accommodating trays 10 each accommodating a glass substrate 20). The substrate accommodating trays 10, except for the lowest and the second lowest substrate accommodating trays 10, are held by the tray holding unit 32. The lowest and the second lowest substrate accommodating trays 10 remain on the table section 33a without being held by the tray holding unit 32.

Then, the elevatable table 33 is moved down by the elevating unit 35. The lowest and the second lowest substrate accommodating trays 10 on the table section 33a are also moved down. While the elevatable table 33 is moved down, the support pins 34 provided inside the supporting base 31 go through the lattice table section 33a and are inserted into the openings 11a of the lowest and the second lowest substrate accommodating trays 10 sequentially.

When the elevatable table 33 is moved further down, as shown in Figure 16, the top end of each support pin 34 contacts a bottom surface of the glass substrate 20

accommodated in the second lowest substrate accommodating tray **10**. Then, the glass substrate **20** is raised relative to the second lowest substrate accommodating tray **10** positionally relatively while being supported by the support pins **34**. The glass substrate **20**, when completely raised above the second lowest substrate accommodating tray **10**, is held horizontally at a prescribed height while still supported by the support pins **34**.

When the glass substrate **20** is put into this state, the elevatable table **33** is stopped. Then, the glass substrate **20** is released from the support pins **34** and transferred to a prescribed position by a transfer member such as, for example, an adsorption hand.

When the glass substrate **20** is removed as described above, the lowest and the second lowest substrate accommodating trays **10**, from which the glass substrates **20** have been removed, remain on the table section **33a** of the elevatable table **33**.

By repeating the above-described operation, the lowest substrate accommodating tray **10** among the plurality of substrate accommodating trays **10** held by the tray holding

unit 32 is placed on the substrate accommodating trays 10 sequentially on the table section 33a. By the elevatable table 33 moving down, the glass substrate 20 accommodated in the substrate accommodating tray 10 placed on the table section 33a is removed from the substrate accommodating tray 10 while supported horizontally by the support pins 34. The removed glass substrate 20 is then transferred.

As a result, as shown in Figure 17, the plurality of substrate accommodating trays 10 with no glass substrate 20 remain on the table section 33a. These substrate accommodating trays 10 stacked vertically are transferred from the table section 33a.

As described above, the substrate transfer apparatus 30 according to the present invention can remove, with high efficiency, the glass substrates 20 from the substrate accommodating trays 10 stacked vertically. Since the substrate accommodating trays 10 are moved up and down to remove the glass substrates 20 therefrom, the planar size of the substrate transfer apparatus 30 is relatively small and the structure of the substrate transfer apparatus 30 is relatively simple.

The substrate transfer apparatus **30** is also used for placing a glass substrate **20** in each of a plurality of substrate accommodating trays **10** stacked vertically.

With reference to Figures **18** through **25**, an operation of the substrate transfer apparatus **30** for accommodating a substrate **20** in each of the plurality of substrate accommodating trays **10** will be described. Basically, the substrate transfer apparatus **30** operates oppositely to the above-described process.

As shown in Figure **18**, a plurality of substrate accommodating trays **10** stacked vertically with no glass substrate **20** are placed on the table section **33a**. Then, the elevatable table **33** is moved down. Alternatively, the plurality of substrate accommodating trays **10** with no glass substrate **20** may be placed on the table section **33a** after the elevatable table **33** is moved down.

In this state, the support pins **34** are inserted into the plurality of substrate accommodating trays **10**, and the top end of each support pin **34** is above the highest substrate accommodating tray **10**.

Then, still as shown in Figure 18, a glass substrate 20 is transferred by a transfer member such as, for example, an adsorption hand, and is placed horizontally on the top ends of the support pins 34. The elevatable table 33 is moved up and, as shown in Figure 19, the glass substrate 20 is accommodated in the highest substrate accommodating tray 10 among the plurality of substrate accommodating trays 10 on the table section 33a. The elevatable table 33 continues to be moved up to such a position that the highest substrate accommodating tray 10 accommodating the glass substrate 20 is engaged with the engaging claws 32f of the tray holding unit 32.

At this point, the upward movement of the elevatable table 33 is stopped. As shown in Figure 20, the highest substrate accommodating tray 10 is engaged with the lowest engaging claws 32f. Thus, the highest substrate accommodating tray 10 is held by the tray holding unit 32.

Then, the elevatable table 33 is moved down. Thus, the plurality of substrate accommodating trays 10 on the table section 33a are also moved down, except for the highest

substrate accommodating tray **10** held by the tray holding unit **32**. The support pins **34** inside the supporting base **31** are inserted into the substrate accommodating trays **10** placed on the table section **33a**.

As shown in Figure **21**, a glass substrate **20** is transferred by a transfer member and placed horizontally on the top ends of the support pins **34**. The elevatable table **33** is moved up and, as shown in Figure **22**, the glass substrate **20** is accommodated in the second highest substrate accommodating tray **10** (i.e., the highest substrate accommodating tray **10** among the plurality of substrate accommodating trays **10** on the table section **33a**). The elevatable table **33** continues to be moved up until the second highest substrate accommodating tray **10** contacts the bottom surface of the highest accommodating tray **10** held by the tray holding unit **32**. At this point, the upward movement of the elevatable table **33** is stopped.

As shown in Figure **23**, the highest substrate accommodating tray **10** is released from the engagement with the tray side engaging members **32c** of the tray holding unit **32**, and rests on the remaining substrate accommodating trays **10** which rests on the table section **33a**. As shown

in Figure 24, the elevatable table 33 is moved up by a distance corresponding to one substrate accommodating tray 10. The height of the elevatable table 33 is adjusted such that the highest and the second highest substrate accommodating trays 10 are engaged with the engaging claws 32f.

When the height of the elevatable table 33 is thus adjusted, as shown in Figure 25, the highest and the second highest substrate accommodating trays 10 are engaged with the two lowest engaging claws 32f of the tray holding unit 32.

Then, the elevatable table 33 is moved down, and the substrate accommodating trays 10 are also moved down while being on the table section 33a, except for the highest and the second highest substrate accommodating trays 10 each accommodating a glass substrate 20. The support pins 34 are inserted into the substrate accommodating trays 10 on the table section 33a.

By repeating the above-described operation, a glass substrate 20 is placed in the highest substrate accommodating tray 10 among the plurality of substrate

accommodating trays **10** placed on the table section **33a** sequentially. The plurality of substrate accommodating trays **10** in the substrate transfer apparatus **30**, each accommodating a glass substrate **20**, are placed on the table section **33a** while being stacked vertically, and then integrally transferred.

As described above, the substrate transfer apparatus **30** according to the present invention can place, , with high efficiency, the glass substrates **20** in the substrate accommodating trays **10** stacked vertically. Since the substrate accommodating trays **10** are stacked vertically while accommodating the glass substrates **20**, the work efficiency of accommodating the glass substrates **20** is significantly improved.

The substrate accommodating tray **10** in the above example is for accommodating a glass substrate **20** for a liquid crystal display panel. The substrate accommodating tray handled by a substrate transfer apparatus according to the present invention is not limited to such a substrate, and may be a glass substrate for other types of display panels. The substrate handled by the substrate transfer apparatus according to the present

invention is not limited to a glass substrate and may be a synthetic substrate or the like.

In the above example, the elevating unit **35** for elevating the elevatable table **33** uses the ball screw mechanism. The elevating section **33f** may include a belt transport mechanism including a pair of pulleys located vertically and a belt extended around the pulleys, instead of the ball screw mechanism. In this case, the elevatable table **33** is moved up and down by the belt transport mechanism.

The substrate transfer apparatus **30** does not need to include the elevatable table **33** or the elevating unit **35**. Provision of a plurality of support pins **34** corresponding to the openings **11a** of the substrate accommodating trays **10** below the tray holding unit **32** is sufficient. In such a structure, the glass substrate **20** may be removed from the substrate accommodating tray **10** as follows. Among the plurality of substrate accommodating trays **10** held by the tray holding unit **32**, only the lowest substrate accommodating tray **10** is released from the tray holding unit **32**. The lowest substrate accommodating tray **10** is moved downward by its own weight.

The glass substrate **20** accommodated in the lowest substrate accommodating tray **10**, which is moving down, is removed using the support pins **34**. This further simplifies the structure of the substrate transfer apparatus.

In this case, the moving speed of the substrate accommodating tray **10** is reduced, such that the glass substrate **20** is removed with certainty with no risk of being damaged.

The support pins **34** do not need to have a length sufficient to be inserted into the plurality of substrate accommodating trays **10**. The support pins **34** may have a length sufficient to be inserted into only one substrate accommodating tray **10**. In this case, each time the glass substrate **20** is removed from one substrate accommodating tray **10**, the substrate accommodating tray **10** may be transferred. This further reduces the size of the substrate transfer apparatus.

In the case where the support pins **34** have a length sufficient to be inserted into the plurality of substrate accommodating trays **10**, one substrate accommodating tray **10** may be received by the substrate transfer apparatus

30 by an appropriate method without using the elevatable table 33 or the tray holding unit 32. The received substrate accommodating tray 10 is moved down such that the support pins 34 run through the openings 11a of the substrate accommodating tray 10. Thus, the glass substrate 20 accommodated in the substrate accommodating tray 10 is supported by the support pins 34 and thus removed. By repeating this operation, the substrate accommodating trays 10 are stacked vertically when a glass substrate 20 is removed from each substrate accommodating tray 10.

As described above, a substrate transfer apparatus and a method for removing a substrate according to the present invention can remove, with high efficiency, a substrate from each of a plurality of substrate accommodating trays stacked vertically. Since the substrate accommodating trays, from which the substrates have been removed, are stacked vertically, the subsequent work of transferring the substrate accommodating trays can be performed with highly efficiently. Similarly, a method for accommodating a substrate according to the present invention can place, with high efficiency, a substrate in each of a plurality of substrate accommodating trays stacked vertically.

A substrate transfer apparatus according to the present invention has a small area and is compact, and is economical.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly construed.